PUTTING RESEARCH TO WORK **BRIEF**

Bridge Piles: More Capacity Over Time?

The majority of bridge structures designed by the Wisconsin Department of Transportation are supported on deep foundations consisting of driven piles. In recent years, WisDOT has spent between $1.8 million and $2.9 million annually on these piles.

Soil/pile set-up is the time-dependent increase in pile capacity after pile driving, which can contribute significantly to long-term pile capacity. The exact mechanism by which this occurs is not fully understood, but the majority of set-up is likely related to the dissipation of excess porewater pressures within soil that is displaced and disturbed as the pile is driven, and subsequent remolding and reconsolidation of that soil. Additional set-up may occur due to aging.

What's the Problem?

Depending on soil type, set-up has been demonstrated to account for increases of up to 12 times the initial end-of-drive pile capacity; two studies have proposed that a set-up factor of 1.2 times the initial value would be conservative in all soil types at all depths. Incorporating the effects of set-up into pile design may make it possible to reduce pile lengths, reduce pile sections or reduce the size of driving equipment, any of which would result in cost savings to WisDOT.

However, performing detailed set-up characterization while a construction project is in progress generally involves extra equipment, software and human resources, and can be expensive and time-consuming. Most WisDOT bridge projects involve a relatively small number of piles, and the cost of testing to characterize set-up on these projects would likely exceed the savings generated by the test results. If pile set-up could be estimated relatively accurately rather than measured directly, WisDOT engineers could reduce pile size and still feel confident that state bridges would perform adequately.

Research Objectives

This study's objective was to determine whether it is possible and practical to estimate set-up during design with reasonable accuracy, using information obtained during routine subsurface exploration and without substantially increasing costs. The researchers' goal was to identify a viable estimation method for field-testing on WisDOT projects.

Study Design

A literature search was conducted to find all currently available papers on soil/pile set-up. More than 100 papers were reviewed.

Results

Measuring Set-Up: To measure set-up in the field, a pile's capacity must be determined at least twice, first at the end of driving. The second determination should be delayed as long as possible. Capacity determinations can be achieved with top- or bottom-loaded static load tests, or with dynamic testing and subsequent analysis. Once set-up has been characterized, it can be applied to the design of future piles that will be driven through the same strata.

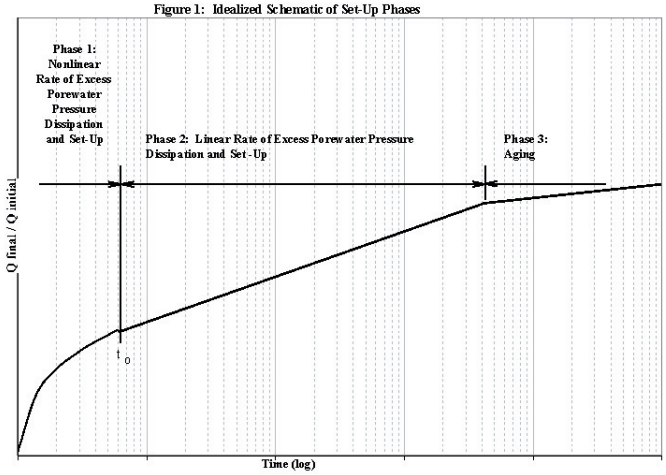
Predicting Set-Up: Through the literature review, researchers identified several exploration-phase field tests of potential value in predicting set-up. The Standard Penetration Test-Torque test was selected as offering the best combination of applicability of results, ease and simplicity of performing the test, and cost. In this test, a standard split-barrel sampler is driven into the soil, and torque is applied to the drill rod in a controlled manner to rotate the sampler, immediately after driving and again after a period of time. The measured torque is an indication of the unit shearing resistance between the sampler and the soil. By staging the application of torque applied to the sampler, time-dependent char-

Project Manager

"This research and the follow-up SPT-T study have the potential to save WisDOT thousands of dollars every year in materials and equipment costs."

–Jeffrey Horsfall
WisDOT Soils and Foundation Engineering Unit
jeffrey.horsfall@dot.state.wi.us

Figure 1: Idealized Schematic of Set-Up Phases



According to conventional consolidation theory, soil experiences a linear increase (with respect to the log of time) in effective vertical and horizontal stress during Phase 2 of set-up. During this phase, the soil consolidates and gains shear strength (Fig. 1, page 23 of final report).

acteristics of sampler/soil resistance can be determined. Time-dependent torque increase is a measure of "set-up" between the sampler and the soil.

The sampler in the SPT-T test uses a conventional drill rig, with relatively minor equipment requirements beyond those used for conventional drilling and sampling, and with proper training may require no additional personnel. It can be used in all soil types, and by obtaining both peak and residual torque values, it may provide insight into soil sensitivity.

The literature review also identified a number of empirical relationships that have demonstrated reasonable accuracy in estimating or predicting set-up, including the set-up factor of 1.2 times the initial end-of-drive capacity mentioned above. However, several factors limit the widespread use of the relationships, including the complexity of the mechanisms contributing to set-up.

Further Research and Implementation

A follow-up project (0092-04-09) to field-test the SPT-T, "Investigation of Standard Penetration Torque Testing (SPT-T) to Predict Pile Performance," is now under way. Researchers will develop standardized SPT-T test procedures and equipment, and conduct field-testing on a limited number of sites for which good-quality set-up data is available for comparison. The SPT-T test results will be compared and potentially correlated to design pile adhesion values for cohesive soils, and to set-up data for all soil types.

If the findings indicate good correlation, WisDOT may begin SPT-T testing on selected projects on a more routine basis. Test results will be compared with set-up measured during construction to develop a more complete database of information that could be expanded to all areas of the state.

Benefits

This research is the first step toward WisDOT potentially incorporating the effects of set-up into pile design, which would generate cost savings in materials and equipment. To illustrate set-up determination and to give an example of set-up magnitudes that have been documented in Wisconsin, the researchers' final report includes results from a single indicator test pile from a Milwaukee project. The report also includes an annotated bibliography with summaries of 18 studies on pile set-up.

This brief summarizes Project 0092-00-14, "Estimating Soil/Pile Set-Up," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research, Development & Technology Transfer Program, 4802 Sheboygan Ave., Madison, WI 53707.

Nina McLawhorn, Research Administrator

Investigators

"This study could make a major contribution to building bridges in the state of Wisconsin."

–Tuncer Edil
University of Wisconsin-Madison
edil@engr.wisc.edu

"WisDOT's study of estimating set-up indicates the department's commitment to economical pile design."

–Van E. Komurka
Wagner Komurka Geotechnical Group Inc.
komurka@wkg2.com

Not pictured:
Alan B. Wagner,
Wagner Komurka Geotechnical Group Inc.